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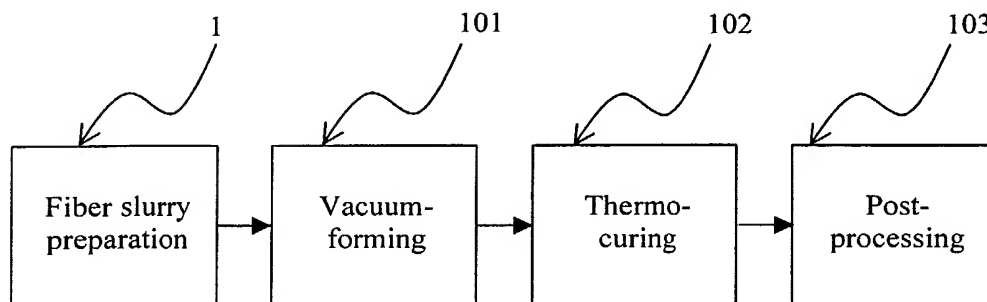
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(72) Inventors: **TOH, Peng, Seng** [SG/SG]; Grenidea Technologies, 67 Ayer Rajah Crescent, 07-18/19/20, 139950 Singapore (SG). **XU, Yan** [SG/SG]; Grenidea Technologies, 67 Ayer Rajah Crescent, 07-18/19/20, 139950 Singapore (SG). **SLOW, Meng, Lee** [SG/SG]; Grenidea Technologies, 67 Ayer Rajah Crescent, 07-18/19/20, 139950 Singapore (SG).
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: IMPROVED MOLDED FIBER MANUFACTURING



(57) Abstract: Molded fiber products using agriculture residues are economical and environmentally beneficial. Molded fiber manufacturing is different from molded pulp. The present invention discloses a method of and an apparatus for the manufacturing of molded fiber shaped body (10) using low consistency fiber slurry (12) subject to vacuum-forming and thermo-curing. The use of porous material as mold inserts for both vacuum-forming (101) and thermo-curing (102) stations provides improved productivity and enables ease of mold release. The incorporation of self-cleaning techniques further ensures consistent performance of the manufacturing system.



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Improved Molded Fiber Manufacturing

This invention relates to a method of and an apparatus for improving the manufacturing of molded fiber shaped body.

Background

Products made of molded fiber are environmental friendly. Raw materials for manufacturing molded fiber products are derived from agriculture residues which are usually treated as waste. Unlike pulp, fibers from agriculture residues do not need to be rigorously treated before they are used. When molded fiber products are disposed, they are biodegradable and are emission neutral.

Molded fiber shaped bodies can be used as packaging for food, industrial goods, consumer products and many others. It has very good cushioning property and is ready to be used without the need to cut, bend and fold. It is also light and stackable which reduce storage and shipping space. Molded fiber packaging is a cost economical and environmental friendly choice to replace existing plastics and paper packaging.

Vacuum thermoforming method using low-consistency fiber slurry with water-based adhesive binder can be used for producing molded fiber shaped bodies (refer to patent application SG20016232-2). A low-consistency fiber slurry, usually with less one percent (weight) of fiber in water, is poured into the vacuum-forming mold. Existing vacuum-forming molds consist of drilled holes evenly spaced out which allow fluids and air to pass through. The drilled holes are connected to vacuum means. A sieve must be placed over the vacuum-forming mold to ensure a uniform layer of fiber is deposited on its surface after the activation of the vacuum-forming process. The sieve is usually made of wire mesh shaped according to the mold. The sieve serves two main purposes. Firstly, to act as filter such that fibers are retained on the sieve while the fluid is drawn away by vacuum force; Secondly, to redistribute the vacuum force evenly over its entire surface so that the deposition of fiber is uniform.

The deposited fibers are subject to curing by heat and pressure to produce the final product. The applied heat and pressure on the mold will also cause the sieve to deteriorate rapidly. As a result, the wire mesh sieve will be worn and torn after a limited number of cycles in the thermoforming process. Furthermore, fiber residues entangled on the sieve accumulate after every cycle reduces the vacuum efficiency and distribution. Eventually, the sieve will be choked and ceased to function.

The use of wire mesh sieve has been proven in the manufacturing of paper and molded pulp products. However, there are several disadvantages such as frequent changing of the sieve is required due to wear and tear; the surface of the product in contact with the sieve is usually coarsely textured and may not be aesthetically acceptable to some users; the wire sieve needs to be secured onto the mold and this takes up valuable space on the mold. It is apparent that productivity is significantly affected due to the need to clean and eventually replace the wire mesh sieve.

Although molded pulp shaped bodies has been using wire mesh sieve in the manufacturing process rather successfully, molded fiber is different in many aspects. Fibers from agriculture residues are lignocelluloses. Molded fiber uses adhesive to bind fibers together produces a tough shaped body that is mechanically stronger than equivalent molded pulp. Molded pulp does not need external adhesive as cellulose fibers can be bonded to one another naturally. As a result, molded fiber manufacturing causes the wire mesh to wear out faster than molded pulp. Mold release is yet another problem to molded fiber manufacturing due to the use of adhesive. Alternative mold design and materials have to be sought in order to overcome the problems associated with the use of wire mesh sieve in the manufacturing of molded fiber shaped bodies.

The energy consumption for producing molded pulp is considerably high. Much of the energy is consumed in drying the molded shaped body by heat. Two main techniques of thermal drying of molded pulp exist: drying tunnel and dry-in-the-mold. The drying tunnel technique takes up huge space and causes the molded shaped body to buckle. The dry-in-the-mold technique applies heat to the molded shaped body while it is still in the mold and hence produces products with better accuracy and performance. It also requires a smaller space. Most of the existing literatures addressed dry-in-the-mold as cure-in-the-mold. This is technically misleading as molded pulp does not need curing, it merely needs to be dried. Molded fiber, on the other hand, needs thermal curing to chemically activate the adhesive and thus bind the lignocelluloses fibers together. Drying is a physical phenomenon whereas curing is a chemical phenomenon.

It is understandable that solving the abovementioned problems will lead to huge productivity improvement in manufacturing molded fiber products and thus their cost competitiveness.

Prior Arts

US patent US6083447 titled "Fibrous Slurry vacuum-forming" discloses a method and an apparatus for producing molded pulp articles using porous mold that dips into a fibrous slurry. This invention does not resolve the thermoforming process where heat and pressure are applied. Mold release issue is not discussed and it is limited to molded pulp instead of molded plant fiber.

US patent US5529479 titled "Thermoformable mat mold with hot gas supply and recirculation" discloses the use of porous mold for the release of gas from the mold cavity when the plastics parts are being heated.

US patent US6302671 titled "Porous mold for a roll support and spacing structure" describes a method porous mold for fabricating a formed mold pulp structure to protectively support at least one roll of web material.

Summary of Invention

The present invention of manufacturing molded fiber shaped bodies discloses improved manufacturing method and apparatus using vacuum-forming and thermo-curing of low-consistency fiber slurry.

It is an objective of the present invention to increase the productivity of manufacturing molded fiber shaped bodies. Porous materials fabricated into the desired shape are used as mold inserts in the vacuum-forming molds and the thermo-curing molds to eliminate the use of sieves. As a result, production downtime is reduced as there is no longer a need to maintain and change sieves on the vacuum-forming and thermo-curing molds. With the use of porous material as mold inserts in the vacuum-forming process, a uniform layer of wet fiber is deposited on the porous mold inserts after the application of vacuum to draw fluid away from the slurry. The porous mold insert redistributes the vacuum force evenly over its entire surface. The porous mold inserts have open and interconnected pores to allow fluids and air to pass through from one surface to another. The pore size of the porous mold insert range between 5 micrometer to 200 micrometer depending on the size distribution of the fiber material. It is preferred that the pore size is smaller than the smallest fiber size in order not to cause blockage to the pore channels.

Another objective of the invention is to enable the finished molded shaped bodies to be released from the thermo-curing molds after the thermo-curing process. The thermo-curing process uses a pair of mating molds where heat and pressure are applied. The applied heat and pressure produces steam and the steam must be released from the closed mating molds. At least one of the mating molds' inserts is made of porous material so that steam can be extracted away by vacuum means. In the case where only one mold has mold inserts that are made of porous material, then the other mold surface is to be sufficiently roughened to prevent the heat cured molded fiber shaped body from sticking to the mold. The porous mold surface and the roughened mold surface have a roughness in the range of 8 micrometer to 40 micrometer. Larger than 40 micrometer roughness is allowable but will affect the aesthetic appearance of the finished shaped body. Unlike smooth surfaced mold, the designed roughness enables a large number of microscopic air pockets to be built up between the mold surface and the molded fiber shaped body. The air pockets reduce the adhesion of the molded fiber shaped body to the thermo-curing mold. It is to be noted that the surface of the porous mold inserts are inherently rough. The porous materials, preferably porous metal, have sufficient mechanical strength to withstand the amount of heat and pressure applied in the thermo-curing process. The heating temperature ranges from 100 degree C to 200 degree C. The applied pressure is in the range of 0.5 MPa to 5 MPa.

Yet another objective of the invention is to reduce the energy consumption in manufacturing molded fiber shaped body. Most of the energy is consumed in the thermo-curing process where large amount of thermal energy is used to dry excessive water in the wet fiber shaped body. It is understood that reducing the amount of water in the wet fiber shaped body will reduce the thermal energy. The present invention optimize the use of mechanical dewatering means to reduce the water content in the wet fiber shaped body formed by the vacuum-forming process. The vacuum-forming process uses a pair of matching molds namely top and bottom molds. The top and bottom molds are opened to allow the fiber slurry to be added. Water in the fiber slurry is extracted away by vacuum means through the porous mold inserts to form a uniform layer of wet fiber shaped body on the bottom mold. In order to extract more water out of the wet fiber shaped body, the top mold and bottom mold are closed and

sealed to prevent air infiltration during vacuum dewatering of the wet fiber shaped body. Simultaneously, the top mold and bottom molds apply a slight pressure to the wet fiber shaped body. The mechanical dewatering process stops when the water content in the wet fiber shaped body reaches some pre-determined level, usually in the range of 20% to 50% (wt). It is to be noted that if the top and bottom molds are not sealed when closed, vacuum dewatering will not be effective as ambient air instead of water in the wet fiber shaped body will be extracted.

Yet another objective of the present invention is to reduce maintenance by incorporating built-in self-cleaning means for the porous mold inserts. The self-cleaning means include the use of ultrasonic transducers and back-flushing. The vacuum-forming porous mold inserts are susceptible to clog due to fibers entrapped in the pores. Clogged vacuum-forming mold inserts will affect molded fiber shaped body uniformity and increase energy consumption. Eventually, the clogged vacuum-forming mold inserts will cease to function. According to the present invention, the vacuum-forming mold inserts are cleaned with ultrasonic meaning and back flushing.

Description of Drawings

Figure 1 is the block diagram of the improved molded fiber shaped body manufacturing process.

Figure 2 shows the cross-section view of the vacuum-forming station at an opened position with fiber slurry in the fiber slurry container.

Figure 3 shows the cross-section view of the vacuum-forming station with the top mold and bottom mold closed.

Figure 4 shows the cross-section view of the thermo-curing station at an open position and wet fiber shaped bodies are placed on the bottom mold inserts.

Figure 5 shows the thermo-curing station at a closed position.

Figure 6 shows an exemplary system with both vacuum-forming and thermo-curing station side by side to facilitate the transfer of wet fiber shape body.

Figure 7 shows an exploded view of the vacuum-forming bottom mold with a porous mold insert, mold platform with openings and the vacuum chamber with slurry container.

Specific embodiments of invention

The improved molded fiber shaped body manufacturing process consists of four major steps. These are (1) fiber slurry preparation; (2) vacuum-forming and (3) thermo-curing and (4) post-processing.

The manufacturing process begins with the preparation of fiber slurry. Sufficiently refined plant fibers such as fibers obtained from palm oil, coconut coir, hemp, kenaf

and other fibrous plants are added to a mixer tank. The mixer tank can be pre-filled with water or water can be added simultaneously with the fiber. The amount of fiber is 0.1 to 5 percent (wt) with respect to 99.9 to 95 percent (wt) of water. The fibers are agitated by an agitator such as an impeller to disperse them in the water. The low consistency fiber mixture is sufficiently agitated until a homogenous slurry is obtained. Water based adhesive binder is then added to the mixer tank and the entire mixture is continuously agitated. The agitation action causes the adhesive binder to attach to the fiber. Functional additives such as sizing agent, wet strength agent and small amount of mold release agent such as paraffin wax are added to the slurry. The entire mixture is agitated until a homogenous mixture is obtained. The fiber mixture slurry is ready to be fed to the vacuum-forming process. The fiber mixture slurry is usually stored in a buffer tank with sufficient capacity for feeding to multiple vacuum-forming thermo-curing machines. The buffer tank is constantly agitated to ensure that the fiber slurry remains in a homogenous phase.

The purpose of the vacuum-forming process 101 is to produce a wet fiber shaped body 10 from the fiber slurry 12. The wet fiber shaped body 10 is of the desired shape, thickness and uniformity. The water content in the wet fiber shaped body 10 is controlled such that it should not be too wet to consume too much of thermal energy in the thermo-curing stage; and it should not be too dry such that the thermo-curing process 102 cannot fully activate the adhesive to bind the fibers.

The vacuum-forming station 101 consists of a top mold 30 and bottom mold 20. The top mold 30 is a male mold and the bottom mold 20 is a matching female mold with the desired shape contour. The top and bottom molds 30 & 20 are precisely fabricated and match one another when closed. Guiding means such as guide pins can be used to assist in the alignment of the top and bottom molds 20 & 30 during closing. The bottom mold 20 consists of three major parts: fiber slurry container 28, mold platform 21 and porous mold inserts 22. The fiber slurry container 28 is a water-tight container attached to the mold platform 21. The mold platform is made of non-porous material and sits on a vacuum chamber 23 connected to vacuum means 15 such as a vacuum pump. The vacuum chamber 23 can also allow compressed air to pass through when vacuum means 15 are not in use. Suitable sealing means are applied to ensure that mold platform 21 and the vacuum chamber 23 are joint together in an air-tight manner. The mold platform 21 has a plurality of openings 24 to house the mold inserts 22. The mold inserts 22 are fabricated into the desired shape contour and can be tightly inserted into the openings 24 on the mold platform 21. Positive attachment means such as screws can be used to fix the mold inserts 22 onto the mold platform 21. The porous mold inserts 22 have open pores that permit air and fluids to pass through from one side to another. In this case, the shaped contour surface of the porous mold inserts 22 is connected to the vacuum chamber 23 through the pores.

In one embodiment of the present invention, the top mold 30 of the vacuum-forming station 101 is constructed in a similar manner as the bottom mold 20. The top mold also consists of two parts: the male porous mold inserts 31 and the mold platform 32. Vacuum chamber 33 is built into the mold platform 32. Vacuum means 15 is connected to the vacuum chambers 33. The mold platform 32 has a plurality of openings 36. The male porous mold inserts 31 are fixed onto the openings 36 of the

mold platform 32. The porous mold inserts 31 are connected to the vacuum means 15 through the vacuum chamber 33. The vacuum chamber 33 also allows compressed air to pass through to the porous mold inserts 31. The mold platform 32 is made of non-porous material.

The top mold 30 of the vacuum-forming station 101 is able to move vertically 39 so that the top mold 30 can be lowered and matched precisely with the bottom mold 20. Appropriate guiding means are built into the top and bottom molds 20 & 30 to assist in precision matching when the two molds are closing. When the vacuum-forming top mold 30 and bottom mold 20 are fully closed, the space 45 in between the two molds 20 & 30 is largely air tight. A slight pressure can be asserted on the closed molds 20 & 30 to assist in squeezing water from the wet fiber shaped body 10 while concurrent vacuum suction is applied. The air-tight space 45 enhances the effectiveness of vacuum dewatering since no ambient air infiltration takes place. It should be noted that vacuum dewatering is very energy efficient as compared to thermal dewatering. Without a proper air sealed between the top and bottom molds 20 & 30, vacuum energy will be wasted as ambient air instead of water in the wet fiber shaped body 10 will be extracted.

A suitable amount of fiber slurry 12 is dispensed 29 into the slurry container 28 on the vacuum-forming station 101. The fiber slurry 12 fills up the slurry container 28 and covers the bottom mold 20. Once the appropriate volume is reached, vacuum means 15 is activated to extract the water away. Under vacuum suction, the water in the fiber slurry 12 passes through the pores in the porous mold inserts 22 into the vacuum chamber 23 and out of the vacuum-forming station 101. A layer of wet fiber is then deposited on the surface of the mold insert 22 forming a wet fiber shaped body 10. Due to the average pore size of the porous mold is smaller than the fiber dimension, fibers are prevented from passing through the pores. The uniformly distributed pores help to distribute the vacuum suction evenly over the entire porous mold inserts 22 surface. This results in producing a uniform layer of wet fiber shaped body 10 on the mold inserts 22 surface. At this stage, the wet fiber shaped body 10 usually contains more than 50% of water. The wet fiber shaped body 10 is not cured at this stage.

The top mold 30 is then lowered and pressed the wet fiber shaped body 10 on the bottom mold 20. Vacuum means 15 is activated to draw further amount of water away from the wet fiber shaped body 10 through both the top and bottom porous mold inserts 31 & 22. A pressure of several atmospheres is applied to facilitate water extraction from the wet fiber shaped body 10 by vacuum suction 15 while the top and bottom molds 30 & 20 are tightly closed and air sealed 35 to prevent air infiltration. Vacuum dewatering is most effective without the infiltration of external air as vacuum suction is directed to remove the water molecules in the wet fiber shaped body 10. This process helps to reduce the amount of thermal energy required to dry the product in the subsequent thermo-curing stage 102. This also leads to a reduction of overall production cycle time due to the fact that less time is needed to cure the molded fiber shaped body 80.

After the vacuum-forming process 101, the wet fiber shaped bodies 10 are ready to be thermally cured to activate the adhesive in the wet fiber shaped body 10. The thermo-curing process also presses the molded fiber shaped body 80 to the desired thickness.

In one preferred embodiment, the wet fiber shaped bodies 10 are picked up by the vacuum-forming top mold 30. At the moment when the closed top and bottom molds 30 & 20 begins to separate, vacuum 15 is applied to the top mold 30 while vacuum 15 is cut off from the bottom mold 20. In order to further facilitate the release of the wet fiber shaped body 10 from the bottom mold 20, compressed air is pumped through the vacuum chamber 23 and through the pores of the bottom mold inserts 22. The compressed air coming out of the bottom mold surface helps to propel the wet fiber shaped body 10 away. The pull action of the top mold 30 together with the push action of the bottom mold 20 ensure a smooth transfer of the wet fiber shaped body 10 to the top mold 30. The top mold 30 then moves in the necessary path to transfer the wet fiber shaped body 10 to the thermo-curing station 102.

The purpose of the thermo-curing station 102 is to apply heat and pressure to cure the adhesive and hence bind the fibers together to form the final shape and size. The thermo-curing station 102 also consists of a pair of matched molds 50 & 60 similar to that of the vacuum-forming station 101. The fundamental differences are the ability of the thermo-curing molds in withstanding higher pressure and temperature than the vacuum-forming molds. Temperature in the range of 100 to 200 degree C is applied to the thermo-curing molds. The pressure applied is in the range of 0.5 MPa to 5 MPa. The pair of matched molds is thermo-curing top mold 60 and thermo-curing bottom mold 50. The thermo-curing bottom mold 50 consists of three major parts. These are the thermo-curing mold base 51, mold inserts 52 and heating means 58. The thermo-curing mold base 51 consists of a plurality of cavities to house the mold inserts 52. Sufficient amount of holes 53 serving as air passage are built into the mold base 51 to connect the cavities to the vacuum means 15. These holes 53 also enable compressed air to pass through. When the porous mold inserts 52 are fitted to the thermo-curing mold base 51, they are also connected to the vacuum means 15. The mold inserts 52 are preferably made of porous metals such as copper alloy (bronze) or aluminum alloy. The mold base 51 is heated by heating means 58. In one preferred embodiment, the heating means 58 are electric heating elements fixed to the base of the mold base 51. The heating means 58 can also be heating tubes containing heat transfer fluids that circulate in the mold base 51. Maximum surface contact between the heating means 58 and the mold base 51 must be ensured to obtain high thermal transfer efficiency. It is also equally important to ensure maximum surface contact between the mold base 51 and the porous mold inserts 52 for the similar reason. The major difference in design between the vacuum-forming mold and thermo-curing mold become obvious. Vacuum-forming molds 20 & 30 have large vacuum chambers 23 & 33 and channels to optimize vacuum transfer and water extraction; while the thermo-curing molds 50 & 60 have smaller vacuum channels 53 & 63 and have large surface contact between heating means 58 & 67 and mold inserts 52 & 62 to optimize heat transfer.

The thermo-curing top mold 60 also consists of three major parts which are the mold base 61, mold inserts 62 and heating means 67. The top mold inserts 62 are precisely matched with the corresponding bottom mold inserts 52. When the top mold 60 and bottom mold 50 are fully closed, it leaves a gap which is equal to the thickness of the dried molded fiber shaped body 80. Guiding means such as guiding pins can be used to assist in alignment of the top and bottom molds 60 & 50 during closing. An airtight space is created between the two facing surfaces of the top and bottom molds 60 & 50. Vacuum is produced within this space and hence the temperature needed to

vaporize the water content in the wet molded fiber shaped body 10 can be reduced. This is similar to the concept of vacuum oven. The applied heat and pressure cure the adhesive binder in the molded fiber shaped body and shaped it into the final desired shape and thickness. The steam due to vaporization of the water content in the molded fiber shaped bodies 80 escape through the vacuum channels 53 & 63 and out of the station 102. Upon the completion of the thermo-curing cycle, the top and bottom molds 60 & 50 then open to release the molded fiber shaped body 80. Compressed air blows through the vacuum chamber 54 helps to detach the molded fiber shaped body 80 from the mold insert 52. Either the thermo-curing top mold 60 or an addition pick and place means can be used to move the molded fiber shaped body 80 to the appropriate collection area. Similarly, compressed air blow also helps to detach the molded fiber shaped body from the top mold inserts 62.

Mold release is a major problem in molded fiber shaped body manufacturing. The present invention uses porous mold inserts and roughened surfaces to reduce the adhesion of the molded fiber shaped body to the mold surface. It is to be noted that the surface of a porous mold is sufficiently rough. In the case when the top mold inserts are not made of porous material, then the surface of the top mold inserts is to be sufficiently roughened. One of the commonly technique to roughen the mold surface is by sandblasting usually in the range of 8 to 40 micrometer roughness. The porous molds and roughened mold surfaces created random distributed microscopic air pockets between the molded fiber shaped body and the mold surface that drastically reduce their adhesion to one and another. With the further help of air purge coming out of the porous mold inserts, the molded fiber shaped body 80 can be easily detached from the mold.

The porous mold inserts 22 on the vacuum-forming station 101 are susceptible to clog by fine fibers entrapped in the pores. The entrapped fibers with adhesives must be cleared to maintain the functionality of the porous mold inserts 22. Depending on the types and size of fibers used, as well as the pore size, thickness and porosity of the mold inserts, the porous mold inserts 22 will lose their effectiveness after certain operating cycles.

The present invention discloses the use of ultrasonic cleaning technique and back flushing for performing self-cleaning of the porous mold inserts. Without the incorporation of self-cleaning function, the usability of the porous molds will be limited due to the lost of porosity by fibers and impurities clogging. Ultrasonic transducers are installed on the fiber slurry container 28 of the vacuum-forming mold 20. Water is injected into the bottom mold slurry container 28 and sufficiently covers all the porous mold inserts 22. The ultrasonic transducers are then turned on. The ultrasonic transducer produces ultrasonic sound waves that generate microscopic bubbles which penetrate into the pores. These microscopic bubbles are generated and exploded continuously. The explosion of the microscopic bubbles help to release the trapped fibers and other impurities in the pores. In order to further facilitate the cleaning of the porous mold inserts, back flushing is used. Back flushing is accomplished by pumping compressed air into the vacuum chamber which forces water, fibers and impurities to move out of the porous mold inserts. The combination

of ultrasonic cleaning and back flushing restore the effectiveness of the vacuum-forming mold. The built-in self cleaning function described herein usually takes a few seconds to complete and needs only to be carried out once in several hundred cycles.

The thermally cured molded fiber shaped body can be further processed by the post-processing station 103 such as coating, printing, trimming, sterilizing, and packing. These post-processing methods and apparatus are well known in the arts and are not deliberated herein.

The preferred embodiment of the present invention discloses the use of independent vacuum-forming station, thermo-curing station with each station uses porous mold inserts to enable mold release and improved molded fiber shaped body uniformity. It further disclosed the use of mechanical dewatering means especially vacuum dewatering to achieve high rate of water removal from the wet fiber shaped body which resulted in reducing energy consumption. It further enables self-clean of the porous mold inserts by incorporating ultrasonic transducers and introducing back flushing using compressed air. The preferred embodiment of the invention increases the overall productivity of manufacturing molded fiber shaped body.

Improved Molded Fiber Manufacturing

Claims

1. An improved method of manufacturing molded fiber shaped body comprises of using low-consistency plant fiber slurry subject to vacuum-forming to form a wet fiber shaped body and thermo-curing the wet fiber shaped body to produce the final molded fiber shaped body; wherein porous materials are used as mold inserts for both vacuum-forming and thermo-curing;
2. The improved method of manufacturing molded fiber shaped body as claimed in claim 1 wherein the vacuum-forming process consists of a pair of matching molds with porous mold inserts to produce a uniform thickness wet fiber shaped body under vacuum means.
3. The improved method of manufacturing molded fiber shaped body as claimed in claim 2 wherein the vacuum-forming molds are effectively sealed when closed to achieve highly effective vacuum dewatering of the wet fiber shaped body.
4. The improved method of manufacturing molded fiber shaped body as claimed in claim 1 wherein the thermo-curing process consists of a pair of matching molds with porous mold inserts that are heated by heating means.
5. The improved method of manufacturing molded fiber shaped body as claimed in claim 4 wherein the thermo-curing molds are effectively sealed when closed to reduce the heating energy required to cure the molded fiber shaped body.
6. The improved method of manufacturing molded fiber shaped body as claimed in claim 1 wherein the porous mold inserts in the vacuum-forming molds are cleaned by ultrasonic waves and back-flushing means.
7. The apparatus for manufacturing molded fiber shaped body comprises of three stations namely fiber slurry preparation station, vacuum-forming station and thermo-curing station.
8. The apparatus for manufacturing molded fiber shaped body as claimed in claim 7 wherein the vacuum-forming station comprising of a pair of matching molds arranged in a top and bottom arrangement.
9. The apparatus for manufacturing molded fiber shaped body as claimed in claim 8, the vacuum-forming bottom mold consists of a mold platform with openings for installing porous mold inserts, a fiber slurry container and vacuum chamber for connecting to vacuum means and compressed air means.
10. The apparatus for manufacturing molded fiber shaped body as claimed in claim 7 wherein the vacuum-forming top mold consists of mold platform with openings for mold inserts that matched the shaped the bottom mold inserts.

11. The apparatus for manufacturing molded fiber shaped body as claimed in claim 10 wherein the vacuum-forming top molds platform consists of vacuum chamber that are connected to vacuum means and compressed air means.
12. The apparatus for manufacturing molded fiber shaped body as claimed in claim 11 wherein the vacuum top and bottom molds are able to move vertically and closed with air sealed to prevent ambient air infiltration to the wet fiber shaped body during the vacuum dewatering process.
13. The apparatus for manufacturing molded fiber shaped body as claimed in claim 12 wherein ultrasonic transducers are mounted onto the fiber slurry container.
14. The apparatus for manufacturing molded fiber shaped body as claimed in claim 7 wherein the thermo-curing molds comprises a pair of matching molds arranged in a top and bottom molds arrangement.
15. The apparatus for manufacturing molded fiber shaped body as claimed in claim 14 wherein the thermo-curing top mold consists of non-porous mold base with optimized air passage and heating contact surfaces.
16. The apparatus for manufacturing molded fiber shaped body as claimed in claim 15 wherein the thermo-curing bottom mold consists of non-porous mold base with optimized air passage and heating contact surfaces.
17. The apparatus for manufacturing molded fiber shaped body as claimed in claim 16 wherein the thermo-curing top and bottom molds is able to move vertically and closed to apply heat and pressure to cure the wet fiber shaped body to produce the molded fiber shaped body.
18. The apparatus for manufacturing molded fiber shaped body as claimed in claim 7 wherein the porous mold inserts for the thermo-curing station are preferably made of porous metal.

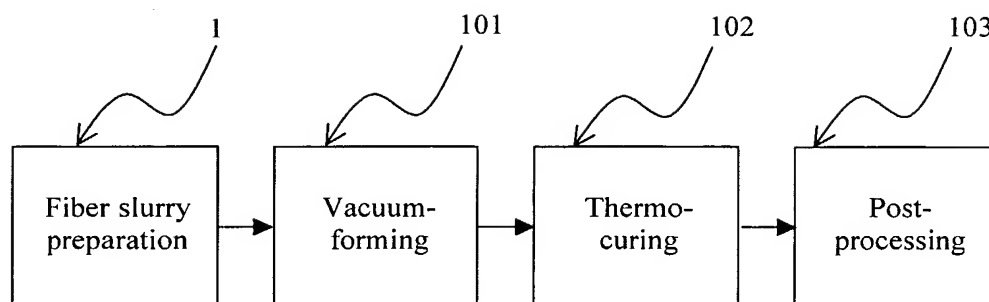


Figure 1

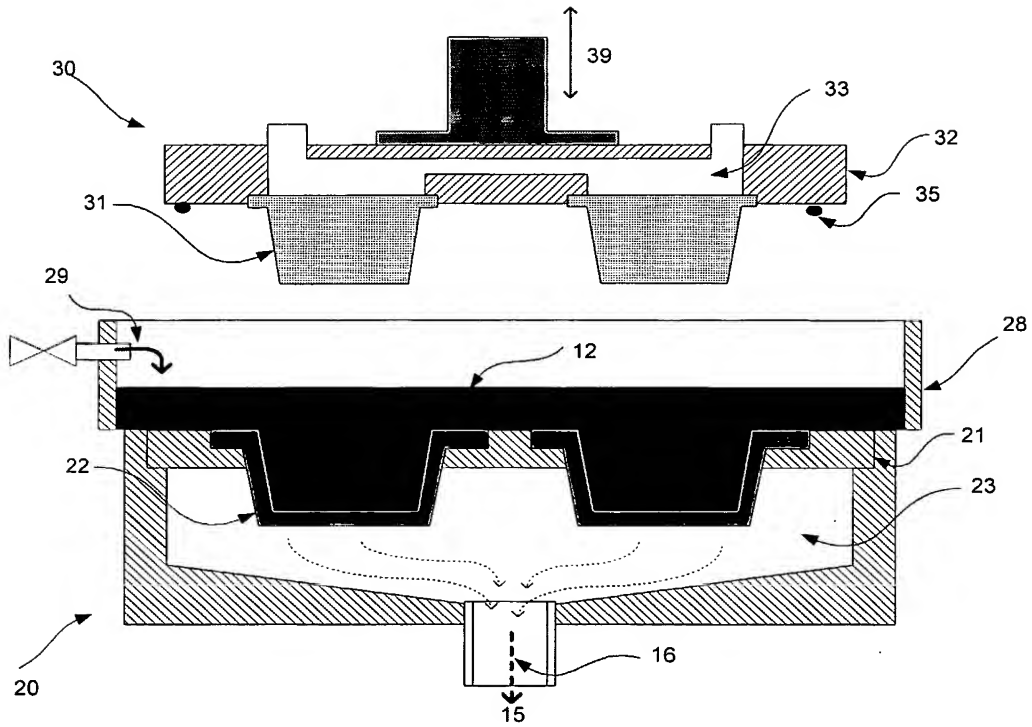


Figure 2

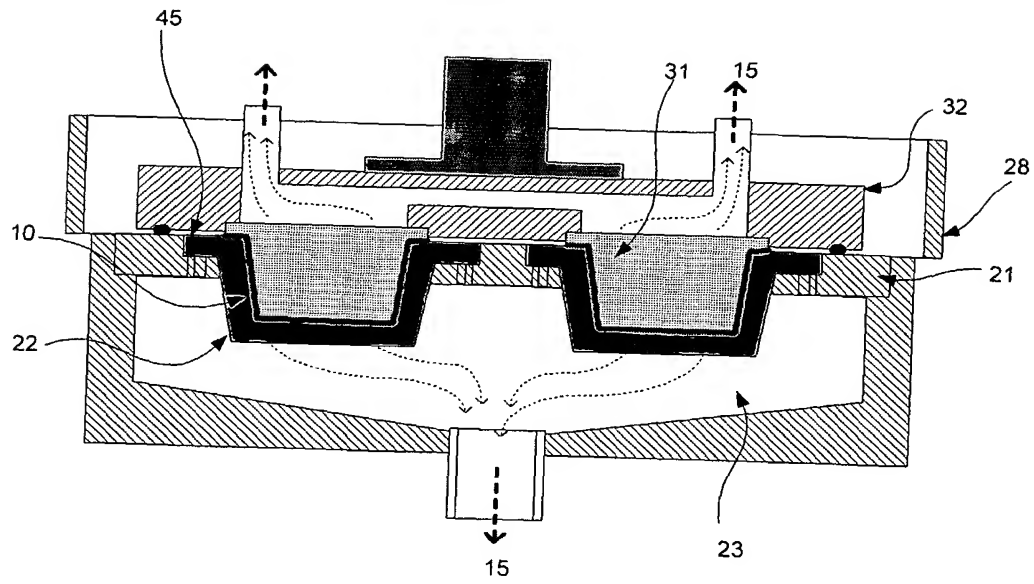


Figure 3

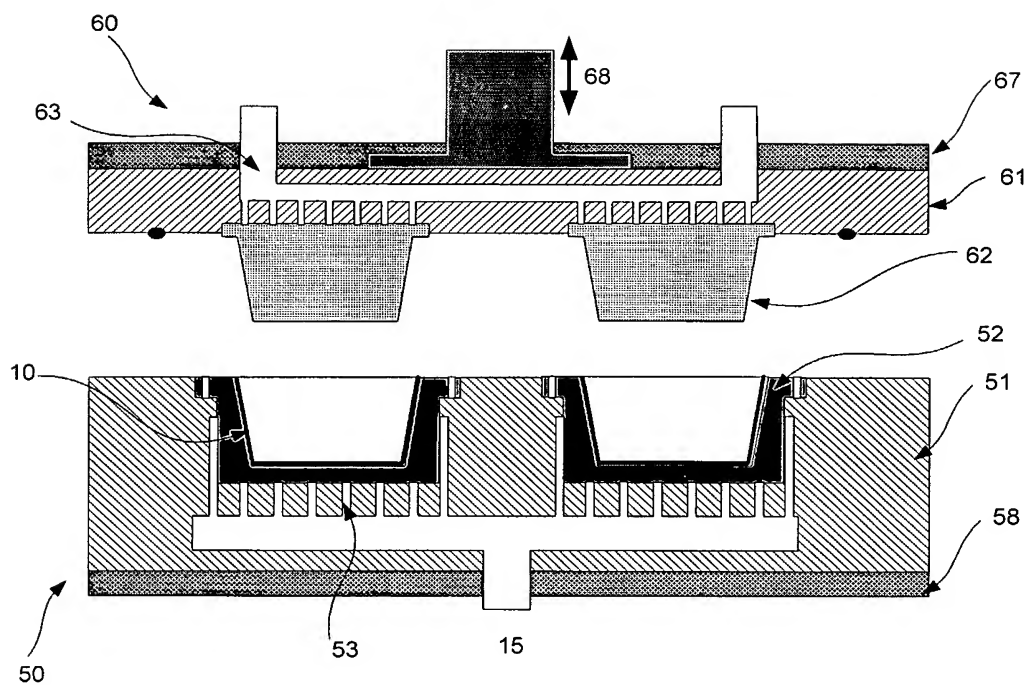


Figure 4

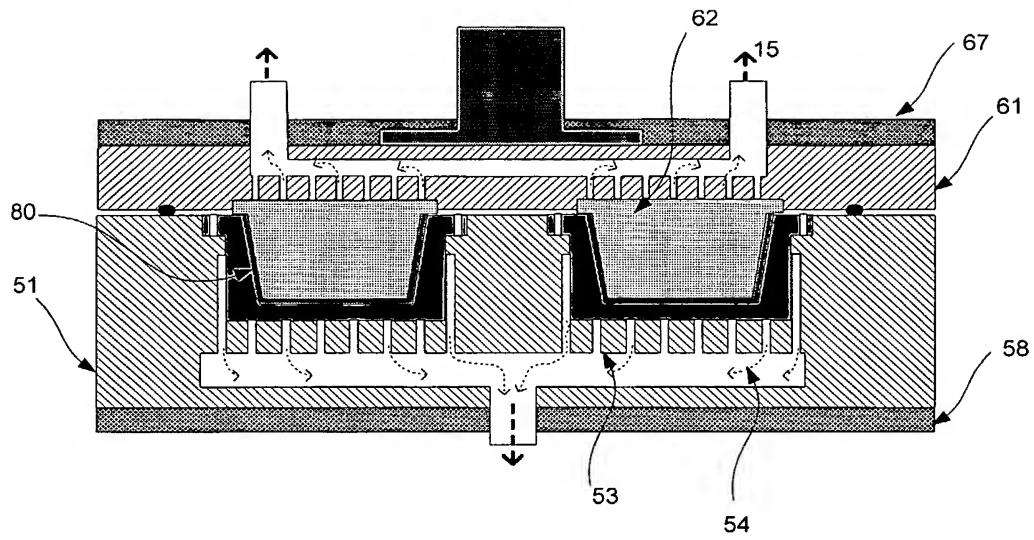


Figure 5

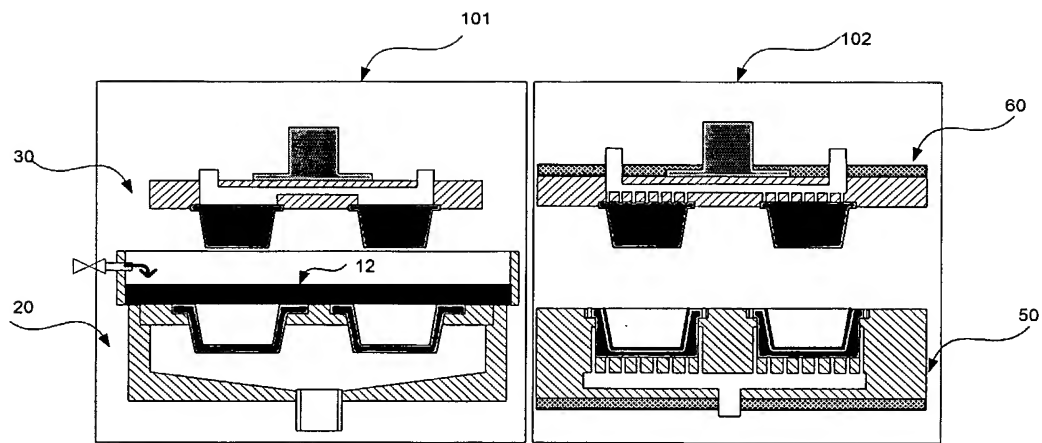


Figure 6

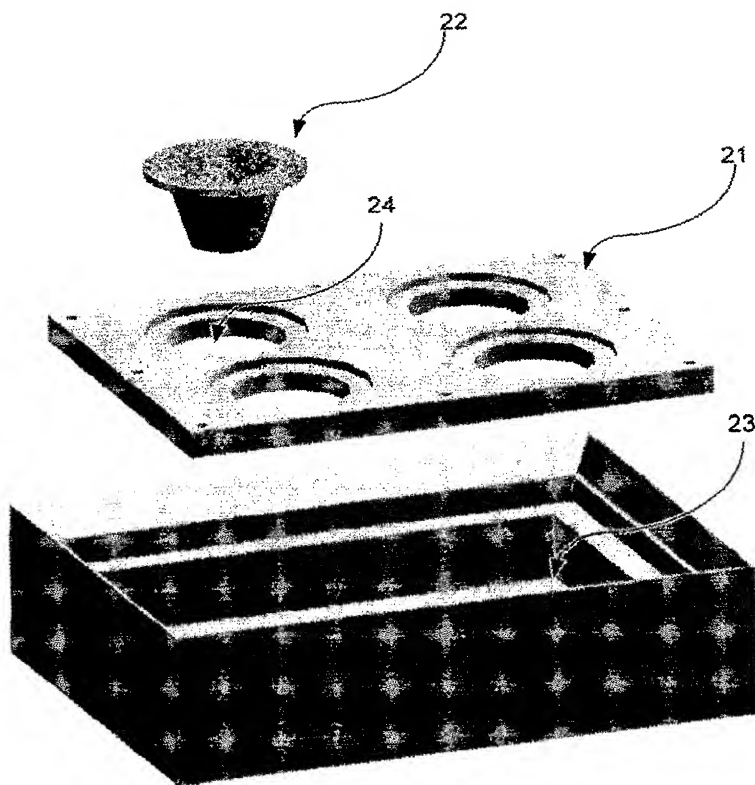


Figure 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG 02/00030

CLASSIFICATION OF SUBJECT MATTER

IPC⁷: D21J 3/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC⁷: D21J 3/00, 3/10, 5/00, 7/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|----------|---|-----------------------|
| A | US 5133834 A (CAPPS) 28 July 1992 (28.07.92) <i>column 4, lines 29 - 31, claim 1.</i> | 1 |
| A | CH 679559 A5 (HARTMANN) 13 March 1992 (13.03.92) <i>claim 1.</i> | 1 |
| A | US 5356518 A (KELLEY) 18 October 1994 (18.10.94) <i>fig. 1, column 3, line 31 to column 4, line 22, claim 1.</i> | 1 |
| | ---- | |

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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Authorized officer

ENDLER K.

Telephone No. 1/53424/417

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Information on patent family members

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